Black Eagle Hydroelectric Facility,
Powerhouse
Great Falls Vicinity
Cascade County
Montana

HAER No. MT-97-A

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PHOTOGRAPHS
HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
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HISTORIC AMERICAN ENGINEERING RECORD

BLACK EAGLE HYDROELECTRIC FACILITY, POWERHOUSE

HAER No. MT-97-A

I. INTRODUCTION

Location:	The Black Eagle Powerhouse is located at the Black Eagle Hydroelectric Facility on the Missouri River at Great Falls, Montana. The powerhouse stands on the north bank of the river just downstream from the dam and headrace. It and several other rcsources at Black Eagle contribute to the significance of the Great Falls Hydroelectric Facilities Historic District.
Quad:	Northwest Great Falls, Mont.
UTM:	Zone 12: 480390 Easting: 5262930 Northing
Date of Construction:	1926-27
Present Owner:	The Montana Power Company
Present Use:	House for hydroelectric generating equipment
Significance:	The Great Falls Hydroelectric Facilities Historic District is significant for its association with the industrial development of Montana and the consolidation of most of the state's electric industry into The Montana Power Company. The district is also associated with John D. Ryan, a promoter of hydroelectric development at Great Falls. The powerhouse at Black Eagle contributes to the significance of the district as a well-preserved example of industrial architecture typical to the hydroelectric industry during the late 1910s and 1920s. The hydroelectric generating equipment installed in the powerhouse is also representative of hydroelectric plant technologies of the period.
Historian:	Mary McCormick Renewable Technologies, Inc. Butte, Montana 59701 September 1996

II. HISTORY

A. INTRODUCTION

This HAER report only documents the govemance system installed in the Black Eagle Powerhouse. This system is original to the powerhouse, constructed as part of the Black Eagle Redevelopment project in 1926-27. Designed and manufactured by the S. Morgan Smith Company of York, Pennsylvania, it is representative of a technological design standard for the period.

B. TECHNOLOGICAL EVOLUTION OF GOVERNANCE SYSTEMS FOR HYDROELECTRIC GENERATING PLANTS, ca. 1880-1945

A govemor is a mechanism designed to regulate a turbine-generator unit at constant speed. It is an essential element of a hydroelectric plant as unit speed determines the frequency of electric current produced. When fluctuations in power demand cause a change in turbine-generator speed, a governor responds by repositioning the gates that control the volume of water supplied to the turbine runner. The turbine gates are moved toward either the open or closed position as needed to maintain the balance between a unit's power input (in the form of water pressure) and power output (in the form of electric current). Thus, turbine-generator speed remains constant.

Early hydroelectric engineers initially adopted simple mechanical governors, which had frequently been used for waterwheel control since the early 1800s. In early mechanical govemors, speed variation in a turbine-generator unit caused rotating flyballs to mechanically motivate a system of ratchet wheels and pawls which, in turn, slowly ratcheted turbine gates toward the open or closed position. Although widely used, mechanical governors generally rendered poor performance, especially at facilities that experienced dramatic changes in load. This was largely because of an inherent inability to adequately balance gate action and speed fluctuations. As a result, early mechanical governors often overshot gate movements, causing the unit to race and hunt.[1]

Thc need for precise turbine-generator speed control prompted a shift to oil-pressure (or less often water-pressure) governors equipped with anti-racing devices during the 1890s.[2] Like its mechanical counterpart, an oil-pressure governor relied on rotating flyballs to sense changes in turbine-generator speed. However, instead of activating gate motion directly, a shift in flyball position moved a distributing valve that controlled the flow of pressurized oil to either one or two cylinders known as servo-motors. When pressurized, the servo-motor(s) moved the turbine gate mechanism to the appropriate position. Gate movements immediately were transmitted from the servo-motor by rods and levers to a restoring mechanism or anti-racing device.

Typically this was a dashpot which retarded flyball action so that the distributing valve returned to the neutral position. The repositioning of the distributing valve for each successive movement of the flyballs and gates smoothed operation of the actuator and prevented overtravel of the gates.[3]

The overall design of the governance system varied from plant to plant, depending, in part, on the number and capacity of the turbine-governor units. The flyballs, distributing valve, and dashpot typically were mounted in a stand configuration on the generating floor by the turbine-generator unit that it regulated. The flyballs were driven by the turbine-generator shaft via a system of gears and jack shaft, or belts and pulleys. They operated the distributing valve by means of floating levers and rods. Small capacity units often were equipped with a single servo-motor located in the base of the governor stand, while large units operated with two servo-motors mounted directly on the turbine casing. Oil for the system was pumped from a sump tank into a closed "pressure tank" where it was pressurized under a cushion of compressed air. Oil from the servo-motor discharged into the sump tank, where it was filtered before further use. Systems with three or fewer units commonly had an individual pressure tank, pump, and sump tank for each governor. A central sump tank and pumping system that serviced the entire governance system was the norm for larger plants.[4]

Oil-pressure governors remained standard hydroelectric practice until after World War II. During this era, however, engineers made significant improvements in their overall operation. By the early 1920s, for example, manufacturers had introduced governors with motor-driven flyballs as well as systems in which the flyballs were mounted directly on the turbine-generator shaft. These configurations eliminated belts and gearing that had required frequent adjustment and lubrication. Some other innovations of the period using a synchronized motor for speed adjustment after a unit had been brought on-line by hand and load limiting devices to prevent the governor from opening the turbine gates beyond a certain position regardless of turbine speed.[5] In the early 1930s, motor-driven flyballs that sensed speed fluctuations through a permanent magnetic generator (PMG) became standard practice. Because PMG flyball drive allowed the governor to be some distance from the turbine, governor manufactures soon offcred "cabinet" governor stands that could be located almost anywhere on the generating floor.[6]

III. TECHNOLOGICAL DESCRIPTION OF THE BLACK EAGLE GOVERNANCE SYSTEM

The governance system at the Black Eagle Hydroelectric Facility is original to the 1926-27 redevelopment. It includes three, oil-pressure governors, one for each of the plant's vertical turbine-generator units. The design and arrangement of the governors and their auxiliary components are standard to the period. The system has sustain few alterations since installation.

Each governor stand is located on the generating floor next to the generator of the unit that it regulates (figure 1). Mounted on the stand are the flyballs in metal casing, the anti-racing device (dashpot), and distributing valve. The flyballs are driven by an AC motor on the casing. Each governor stand is complete with several auxiliary components such as a hand control for gate operation independent of the distributing valve, a synchronizing motor for adjusting turbine speed, a load limiting device, and dials indicating the position of the turbine gates and unit speed.

Each governor operates two servo-motors located in the turbine pit (see figure 1). The servo-motor are arranged on either side of the pit so that the connecting rods from each attach at opposites ends of an operating ring. One of the servo-motor pushes the operating ring in the direction that causes the turbine gates to move toward the open position, while the other servo-motor activates the gate mechanisms toward the closed position. A system of levers and rods translates gate movements to the dashpot.

Typical of installations with three or less units, the governance system at Black Eagle has an independent or self-contained oil-pressure system for each governor. A governor's pressure tank and pump are next to the governor stand on the generating floor, while its sump tank stands near the turbine pit in the powerhouse basement (see figure 1). The pressure tank is a closed reservoir, about 3-foot diameter by 8-foot tall; gages indicating the oil volume and pressure are mounted on the outside of the tank. The oil pump is a Quimbly, screw-type unit direct connected to an A.C. motor. Each oil-pressure system is complete with all necessary piping between the pressure tank, servo-motors, and sump tank.

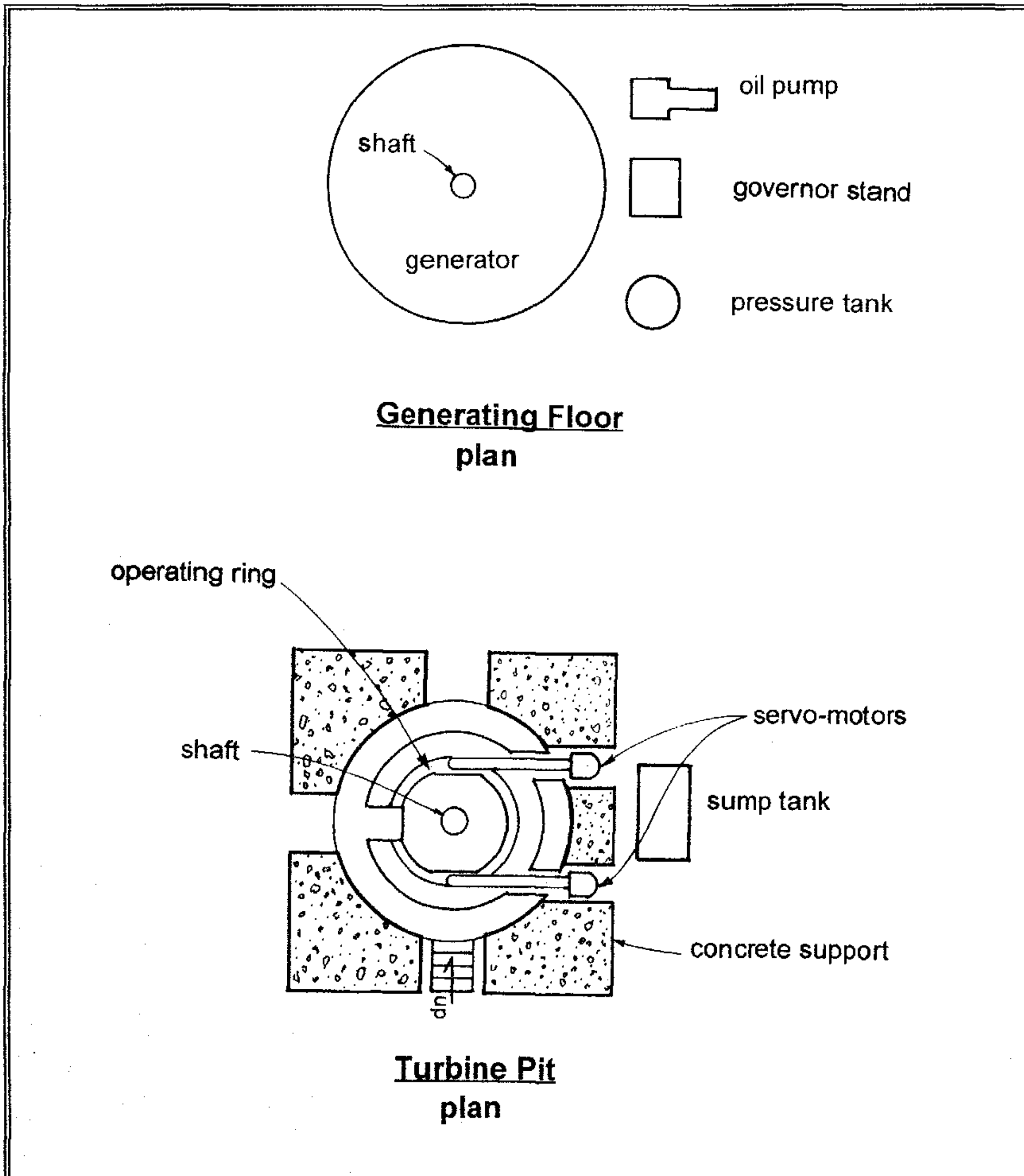

Figure 1. Plans Showing the Layout of Governance Equipment for a Turbine-Generator Unit.

IV. FUTURE OF THE RESOURCE

The Montana Power Company plans to replace the 1926-27 governance system at the Black Eagle Hydroelectric Facility (FERC Project No. 2188) with modern equipment. The Company has sponsored recording the governance system to the standards of the Historic American Engineering Record.

V. ENDNOTES

1. Mark A. Repolgle, "Some Stepping Stones in the Development of a Modern Water-Wheel Governor," *Transactions of the American Society of Mechanical Engineers*, Paper 1110, 27 (1906): 646-647; N.L. Devendorf, "Speed Regulation in the Hydraulic Plant" *Power* 54 (15 November 1921): 765.

2. Replogle, "Some Stepping Stones," 644; and Duncan Hay, *Hydroelectric Development in the United States, 1880-1940*, vol. 1 (Washington, D.C.: Edison Electric Institute, 1991): 88.

3. Devendorf, "Speed Regulation in the Hydraulic Plant," 764-767; W.R. Kepler, "Hydraulic Turbine Governors," *Electric Journal* 65, no. 2 (February 1922): 60-62; H.G. Acres, "Modern Hydraulic Turbines of Large Capacity," *Mechanical Engineering* 45 (August 1923): 469; William P. Creager and Joel D. Justin, eds, *Hydro-Electric Handbook* (New York: John Wiley & Sons, Inc., 1927): 632.

4. Ibid.; F.H. Rogers, "Selection of Auxiliaries for Hydro-Electric Power Stations," *Power* 55 (16 May 1922): 775-776.

5. W.M. White, "Governors for Hydraulic Turbines," *Power Plant Engineering* 27 (1 December 1923): 1178-1182; William P. Creager and Joel D. Justin *Hydroelectric Handbook*, 2d ed. (New York: John Wiley & Sons, Inc., 1955): 898-899.

6. Hay, *Hydroelectric Development in the United States*, vol. 1, 89.

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